Multispectral Solutions, Inc.

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Response to FCC Notice of Inquiry
ET Docket No. 98-153
"Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems."

Submitted to
Federal Communications Commission, Washington, DC

By
Multispectral Solutions, Inc.
Gaithersburg, MD

7 December 1998

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1. Introduction

Multispectral Solutions, Inc. (MSSI) is pleased to submit this document in response to the Federal Communications Commission (FCC) Notice of Inquiry, ET Docket No. 98-153, pertaining to "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems."

MSSI is a Small Business located in Gaithersburg, MD. MSSI was incorporated in February 1989 with the charter to develop advanced electronic systems for both communications and radar applications. Since its inception, MSSI has been actively involved in the development of ultra wideband (UWB) hardware, primarily for U.S. Military and Government applications. MSSI's founder and president, Dr. Robert J. Fontana, has fifteen years of experience in the design, development, test and evaluation of ultra wideband communications systems.

The purpose of our response is to demonstrate to the Commission that:

(a) UWB systems (as defined in Section 2.2.2) represent a mature technology which can satisfy a number of important requirements for military, government and commercial applications;

(b) UWB waveforms can be effectively and easily bandlimited to operate within existing FCC Part 15 frequency allocations for Industrial Scientific and Medical (ISM) and Unlicensed National Information Infrastructure (U-NII) applications;

(c) Many current and projected applications for UWB technology may best be handled through licensed, rather than unlicensed, operation on a non-interference basis; and,

(d) Relaxation of the current Part 15 peak-to-average ratio limitation (20 dB) may be sufficient to permit UWB systems to operate in allocations currently approved for spread spectrum waveforms.

2. Responses to Specific Questions Raised by the Commission in the NOI

2.1 General Characteristics

2.1.1 What types of UWB devices can we expect to be developed?

Over the last almost 40 years[1], there have been numerous approaches for generating short pulse, or ultra wideband, emissions. These have included such techniques as ultra fast risetime sources (e.g., step recovery diodes, IMPATT and TRAPATT diodes, avalanche and breakover devices, GaAs thyristors, etc.) which directly excite a radiating antenna element(s); time-gated oscillators which utilize fast switches to control the pulse duration of a CW source; low power impulse exciters followed by time-gated power amplifiers; and several others. Both time-gated oscillators and low-power impulse exciters can be followed by subsequent bandpass filtering and power amplification.

An important consideration in the design of such UWB devices is the ability to filter and/or otherwise control the total emission bandwidth. Techniques (such as the first mentioned above) which *directly* excite an antenna with a broadband impulse waveform must, by their very nature, result in intentional radiation in restricted bands. However, techniques which permit pulse

[1] Ultra wideband techniques for radar and communications originated with the seminal work of Dr. Gerald F. Ross in the early 1960's. In his 1964 Ph.D. dissertation, Dr. Ross considered the effects of short pulse excitation on microwave circuits including wideband antenna structures, thereby demonstrating the ability to both transmit and receive short pulse emissions. This early work resulted in a series of critical patents in UWB technology when Dr. Ross later directed such efforts at Sperry Research in Massachusetts in the early 1970's.

and/or spectral shaping prior to radiation from an antenna (e.g., the latter two approaches mentioned above) can result in systems which can avoid operation in restricted bands.

Many UWB devices are already under development, primarily for military and government applications. UWB technology has shown distinct advantages for covert communications, high-speed communications in a mobile multipath environment, obstacle and collision avoidance, ground penetration, tagging, and precise positioning applications. These applications take advantage of the very short duration pulses used by UWB devices.

For commercial applications, a bandlimited UWB device is an ideal approach for addressing U-NII requirements for high speed (20 MB/s) wideband digital communications. MSSI expects to demonstrate such a device within the next few months.

2.1.2 What are the frequency ranges and bandwidths expected to be used by UWB devices?

MSSI has either developed, or is in the process of developing, UWB systems and devices for U.S. Government and Military communications and radar operating in the bands 30-50 MHz, 225-400 MHz, 1300-1700 MHz, 2200-2700 MHz, 5400-5900 MHz and 9000-11000 MHz. As illustrated in Appendix A, fractional bandwidths for these systems have ranged from 8% to 50%, representing instantaneous bandwidths of 20 to 2000 MHz. Below 6 GHz, the maximum bandwidth utilized has been 500 MHz. The 9-11 GHz band was utilized for experimental high-speed (350 Mb/s) communications under a program funded by the U.S. Army.

It is anticipated that commercial applications of UWB technology can make use of existing ISM band allocations (902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz) and U-NII allocations (5150-5350 MHz and 5725-5825 MHz).

Higher frequencies (e.g., millimeter wave) are also achievable; however, they are not currently as cost-effective since high volume commercial components have not been produced for these frequency ranges.

Please refer to Section 2.2.2 for a proposed definition of Ultra Wideband emissions, and to Appendix A for specific examples of recently developed UWB equipment for the U.S. Government and Military.

2.1.3 What are the expected total power levels and spectral power densities, peak and average, of UWB devices?

Typical peak power levels for MSSI UWB equipment have ranged from 0.2 Watts to approximately 16 Watts, with average power levels ranging from 2 microWatts to approximately 100 milliWatts. Peak power spectral densities have ranged from 500 pW/Hz to 800 nW/Hz; with average power densities ranging from 0.008 pW/Hz to approximately 5 nW/Hz.

It is anticipated that most commercial applications for UWB systems can be met with peak power levels as currently specified for ISM spread spectrum and U-NII allocations; namely, 1 Watt peak with + 6 dBi antenna gain (4 Watts ERP). Commercially viable short pulse systems can be made to operate within current bandwidth restrictions. (It is important to note that a UWB device exhibits extremely low average power levels when compared to conventional spread spectrum devices.)

Please refer to Appendix A for power levels utilized in recently developed UWB equipment for the U.S. Government and Military.

2.1.4 What are the expected or desired operating distances?

Maximum operating distances for MSSI UWB equipment have ranged from approximately 250 feet (minimum distance for vehicle to roadside communications) to 60+ nautical miles (UAV to ground communications). Thus, UWB systems can and do span a wide range of operating distances; e.g.,

UWB Handheld Radios – 0.5 to 2 miles handheld, 10+ miles LOS
UWB Surface Wave Radios – 5 to 10 miles
UWB Unmanned Aerial Vehicle Links – 5 to 60+ nautical miles
UWB Obstacle Avoidance/Altimeter Radars – 0 to 15,000 feet
UWB Intrusion Detection Radars – 0 to 500 feet.

Again, please refer to Appendix A for ranges recently achieved in UWB equipment for the U.S. Government and Military.

2.2 Regulatory Treatment

2.2.1 Are there certain types of UWB devices or applications that should be regulated on a licensed basis under some other rule part? If so, which rule part?

MSSI believes that a large number of UWB devices and applications can be regulated on a licensed basis. These devices and/or applications include:

(a) All UWB communications devices and communications applications outside of existing ISM or U-NII frequency allocations;

(b) All UWB radar devices and applications.

As an example, a UWB radar altimeter may be licensed to operate within the 4.2 to 4.4 GHz band. However, FCC rules would need to be modified to permit wideband operation over the entire band.

2.2.2 *If provision are made for UWB technology under Part 15, how should we define UWB technology?*

The Defense Advanced Research Projects Agency (DARPA) Panel on Ultra-Wideband Radar defined UWB as "...any radar whose fractional bandwidth is greater than 0.25 regardless of the center frequency or the signal time-bandwidth product.[2]" By fractional bandwidth is meant the ratio of the instantaneous bandwidth (typically defined at its -3 dB points) to the center frequency. While DARPA's definition for UWB is quite general, accommodating a wide variety of possible waveforms (e.g., linear chirp, frequency hopped, wideband direct sequence, etc.), ultra wideband techniques have historically been associated with short pulse, or impulse technologies.

While DARPA's 25% minimum fractional bandwidth definition for UWB may be suitable for some applications, there are numerous examples (cf. Appendix A) in which short pulse systems having much smaller fractional bandwidths have yielded operational systems having unique and useful properties:

a. An ultra wideband (500 MHz BW) obstacle and collision avoidance radar developed for the U.S. Navy and Marine Corps capable of detecting small diameter suspended wires for safety of flight applications (fractional BW = 8.9%);

b. An ultra wideband tag (200 MHz BW) under development for the Department of Transportation for identification of problem (suspended) drivers for the prevention of highway accidents (fractional BW = 13.3%);

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2 Assessment of Ultra-Wideband (UWB) Technology, Report R-6280, prepared by OSD/DARPA UWB Radar Review Panel, July 13, 1990.

c. An ultra wideband (500 MHz BW) backup sensor developed for the National Institute of Occupational Safety and Health (NIOSH) for the detection of obstacles, vehicles and personnel behind large construction and mining vehicles (fractional BW = 8.9%);

d. An ultra wideband (500 MHz), high-speed (20+ Mb/s) video communications link developed for the Defense Advanced Research Projects Agency (DARPA) and the Naval Surface Warfare Center (NSWC) to provide communications between unmanned air vehicles (UAVs) and ground terminals (fractional BW = 8.9%).

(Note: An important commercial application of UWB short pulse techniques may be to provide short-range, high speed, wireless digital communications under Part 15 Unlicensed National Information Infrastructure (U-NII) allocations (ET Docket No. 96-102). In this application, fractional bandwidths could be as low as 100 MHz/(5.825GHz - 5.725GHz) = 1.7% if the full bandwidth of one of the U-NII segments were utilized for transmission. MSSI has demonstrated that short pulse techniques can be effective even at reduced fractional bandwidths.)

The Government and Military have considered these techniques to be "Ultra Wideband", despite their lower fractional bandwidths, because of the use of short pulse technology. Note that in each of these applications, the signal was filtered or otherwise spectrally contained prior to transmission.

Short pulse, wideband but *bandlimited*, techniques have demonstrated unique and/or cost effective solutions to a number of practical and important applications (cf. Appendix A). *It is, therefore, important to note that the term "ultra wideband" does not always refer to indiscriminate and unrestricted spectral utilization.*

We therefore suggest that the Commission adopt the term "Bandlimited Short Pulse", "Bandlimited Impulse" or an equivalent designation, to refer to Ultra Wideband systems utilizing short pulse or impulse technologies in which the power spectral density is filtered prior to transmission. Such systems have the property that, while the bandwidth occupancy is potentially greater than that required by Shannon or Nyquist theory, their spectral densities can be tailored to accommodate existing FCC allocations for more conventional spread spectrum and digital communications.

This bandlimited approach was previously approved by the National Telecommunications Information Agency (NTIA) in granting Stage 4 operational approval to Sperry marine, Inc. for their Intrusion Detection and Alert System (IDAS). An Ultra Wideband bandwidth of approximately 30 MHz (i.e., 35 ns pulse), centered at 1.33 GHz, was authorized.

In a sense, Bandlimited Short Pulse waveforms are better categorized by their duty cycle, or excess bandwidth ratio, rather than by their fractional bandwidth. Bandlimited Short Pulse waveforms have very low duty cycles, unlike constant envelope systems such as direct sequence spread spectrum. For example, a 500 MHz bandwidth C-band (5.4 to 5.9 GHz) short pulse system designed for a 20 Mb/s data rate (cf. Appendix A) has a duty cycle of $(20\times10^6)/(500\times10^6)$, or 0.04. Equivalently, this system can be characterized by an excess bandwidth ratio of 1/(0.04) or 25. The system's fractional bandwidth of 8.8% is irrelevant in terms of the ability to either accommodate the high data rate or counteract multipath effects.

2.3 TV Broadcast and Restricted Bands

2.3.1 Should the rules generally continue to prohibit operation of UWB systems within the restricted bands and the TV broadcast bands?

Yes, UWB systems should continue to be prohibited from operating within the restricted and TV broadcast bands. MSSI believes that the unlicensed use of UWB systems within restricted and TV broadcast bands may result in interference to existing users of these frequencies, particularly as the density of UWB systems increases.

Please see Section 2.4.3 below for further elaboration.

2.3.2 Are there certain restricted bands where operation could be permitted, but not others? If so, which bands and what is the justification?

See Section 2.3.1 above.

2.3.3 If certain restricted bands were retained, what impact would this have on the viability of UWB technology?

The retention of existing restricted bands will have little or no impact on UWB systems which have been properly designed to accommodate output spectral filtering.

2.4 Emission Limits

2.4.1 Are the existing general emission limits sufficient to protect other users of the spectrum, especially radio operations in the restricted bands, from harmful interference? Should different limits be applied to UWB systems?

Part 15 regulations require a maximum 20 dB peak-to-average ratio for all emissions. This limitation appears to be directed at preventing unlicensed emitters from radiating extremely large amounts of power, but at very infrequent intervals. MSSI believes that this peak-to-average ratio limitation should be removed to permit Bandlimited Short Pulse transmissions having very low duty cycles. A *peak power* constraint should, however, remain to prevent the case suggested above.

2.4.2 *Should we specify a different standard for UWB devices based on spectral power density? Should these standards be designed to ensure that the emission appear to be broadband noise?*

The advantages of UWB emissions stem primarily from their very short pulse durations. From the dilation property of Fourier transforms, the shorter the pulse, the wider the Fourier transform. Thus, for a given *peak* power, the shorter the pulse, the lower the spectral power density since this peak power is now distributed over a wider frequency range. However, in a communications system, one must maintain a given energy per bit ratio (Eb/No) to achieve a desired bit error rate (BER) performance. Since Energy = Power x Time, for a fixed Eb/No the peak power must grow as the reciprocal of the pulse duration in order to keep system performance constant.

Thus, in a short pulse system, there is a minimum level for the spectral power density in order to achieve a desired communications performance. Conversely, if one sets the system bandwidth, there is a minimum peak power level which must be used to attain the desired BER. As noted above, the larger this minimum bandwidth, the higher the peak power. Hence, specification of spectral power density for a short pulse system is essentially equivalent to specifying Eb/No, or BER (for either on-off or antipodal signaling). This is an inappropriate specification.

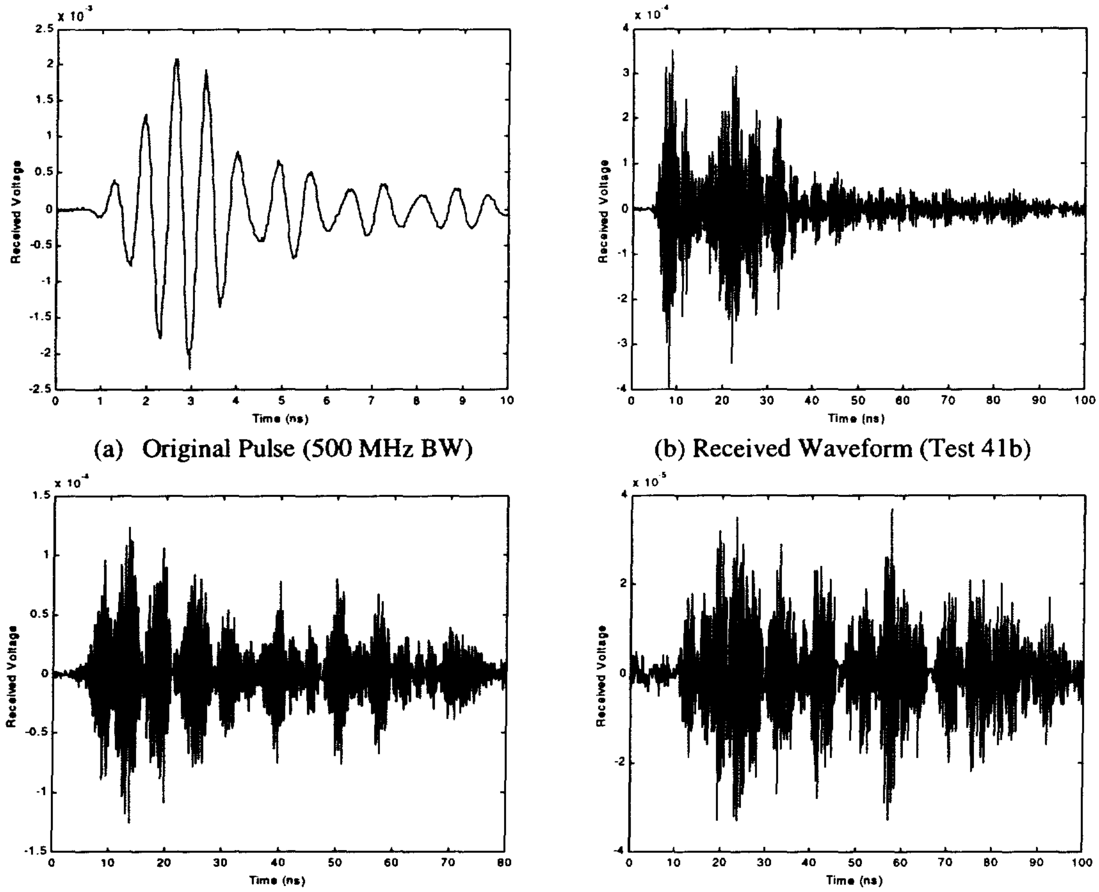
A more appropriate approach would be to specify the maximum peak power *together* with the maximum allowable bandwidth, the latter set by existing Part 15 allocations. In this way, the system designer can adjust performance (as measured by BER) – by controlling the ratio of peak power to instantaneous bandwidth – to achieve a desired communications range.

Finally, a standard designed to ensure that the emission appear to be broadband noise ignores the fact that peak pulse power for short pulse waveforms is highly concentrated in time, very much unlike conventional (e.g., thermal) noise sources.

2.4.3 What is the potential for harmful interference due to the cumulative impact of emissions if there is a large proliferation of UWB devices? Could the cumulative impact result in an unacceptably high increase in the background noise level? Should the Commission limit proliferation by restricting the types of products or should the rules permit manufacturers to design products for any application as long as the equipment meets the standards?

For *unfiltered* UWB systems, the potential for harmful interference due to the cumulative impact of emissions from a large proliferation of devices can be substantial and can result in an unacceptably high increase in the background noise level. Arguments to the contrary have been based upon arguments of low cross correlation between emitters, and extremely low average spectral power densities.

Low cross correlation arguments are based upon the assumption that the probability of overlap for two emitters utilizing extremely short pulses is vanishingly small. Unfortunately, this argument ignores the dispersive effects of the communications channel. For example, Figure 1 below illustrates actual measured data of short pulse propagation in an in-building environment.



(a) Original Pulse (500 MHz BW)

(b) Received Waveform (Test 41b)

(c) Received Waveform (Test 46b)

(d) Received Waveform (Test 51b)

Figure 1. Sample In-building Multipath Measurements.

As observed from the Figure, while the original pulse duration was roughly 2.5 nanoseconds (rms), the channel dispersion resulted in a received pulse waveform which was often well over 100 nanoseconds in duration. Often, the strongest return did not occur on the direct path, but rather was due to a multipath reflection off of an object, wall or door. Hence, the cumulative effects of a proliferation of short pulse emitters can result in a substantive increase in the background noise level.

As for the second argument, as discussed in Section 2.4.2, spectral power density levels are essentially set by the desired bit error rate for short pulse systems. Thus, these cannot be arbitrarily reduced without some form of coherent combining, or equivalently, high processing gain. To date, however, UWB systems have *not* demonstrated high processing gains for several reasons, the primary ones being clock timing inaccuracies and relative platform motions. The latter results in a "time-dilation" effect (similar to Doppler shift in the frequency domain) which essentially prevents coherent combining for nonstationary platforms. Thus, by transmitting hundreds to thousands of symbols per bit, one merely adds to the ambient noise background.

In a June 1994 NTIA document prepared by Mr. Eugene Chang, NTIA noted "potential and serious interference problems may result from the introduction of UWB devices on distress and safety services, passive services, and aeronautical radionavigation service... UWB devices that operate in the VHF/UHF bands were shown to interfere with TV ... and an exception for UWB will be considered only when the benefits to the nation outweigh the disadvantages of the exception." Note that this document referred to *unfiltered* UWB emissions which utilized direct impulse excitation of a radiating antenna element.

2.4.4 Should a limit on the total peak level apply to UWB devices?

Yes. Please refer to Section 2.4.2 above.

2.4.5 Can emissions below or above a certain frequency range be further filtered to reduce the potential for interference to other users of the radio spectrum without affecting the performance of the UWB systems?

In every UWB system designed by MSSI (cf. Appendix A), the UWB spectrum was filtered prior to transmission without adversely affecting system performance. Of course, such filtering is impossible if one can only rely upon the frequency characteristics of the antenna to determine the shape of the output pulse. Thus, as with more conventional communications systems, good engineering practice dictates the use of the minimum bandwidth necessary to achieve the desired performance, and spectral filtering to prevent the potential for interference to other users of the radio spectrum.

2.4.6 Are the existing limits on the amount of energy permitted to be conducted back onto the AC power lines appropriate for UWB devices?

Yes.

2.4.7 What operational restrictions, if any, should be required to protect existing users?

With Bandlimited Short Pulse emissions, no operational restrictions appear necessary to further protect existing users. In fact, for a given peak power, Bandlimited Short Pulse emissions exhibit much lower average powers providing significantly more protection to existing spectrum users as well as safer operation to personnel.

2.4.8 Is the use of UWB modulation techniques necessary for certain types of communication systems; if so, for what purposes?

UWB, i.e. short pulse, modulation techniques appear particularly desirable for communications in high multipath (e.g., mobile and in-building) environments, and for high data rate communications. For military applications, UWB techniques provide a very cost-effective means of achieving low probability of intercept and detection communications.

2.5 Other Matters

2.5.1 Should the prohibition against Class B, damped wave emissions apply to UWB systems or is the prohibition irrelevant, especially in light of the relatively low power levels employed by UWB devices?

Damped wave emissions are typically generated by direct impulse excitation (e.g., spark gap) of a broadband antenna element(s). By their very nature, such emissions are unfiltered and, as such, can cause considerable interference to other services. The prohibition against Class B, damped wave emissions should continue to apply to UWB systems.

3. Conclusions and Recommendations

From the above discussion, the following set of conclusions can be reached for UWB systems and devices:

(a) UWB systems (as defined in Section 2.2.2) represent a mature technology which can satisfy a number of important requirements for military, government and commercial applications;

(b) UWB emissions can be effectively and easily bandlimited to accommodate existing FCC Part 15 frequency allocations for Industrial Scientific and Medical (ISM) and Unlicensed National Information Infrastructure (U-NII) applications;

(c) Many current and projected applications for UWB technology may best be handled through licensed, rather than unlicensed, operation on a non-interference basis; and,

(d) Relaxation of the current Part 15 peak-to-average ratio limitation (20 dB) may be sufficient to permit UWB systems to operate in allocations currently approved for spread spectrum waveforms.

MSSI also wishes to suggest the following rule change for UWB emissions within the U-NII bands. Currently, the U-NII allocation is divided into three 100 MHz regions, only two of which are continuous (5.150 to 5.250 GHz and 5.250 to 5.350 GHz).

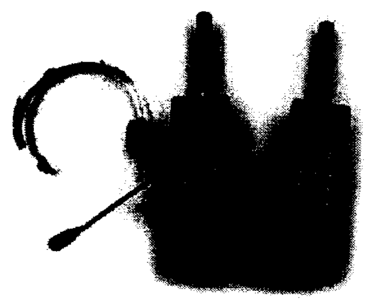
> We recommend that the 200 MHz (contiguous) span from 5.150 to 5.350 GHz be allowed for *filtered* UWB emissions, i.e., Bandlimited Short Pulse emissions, with out of band

constraints below 5.150 GHz and above 5.350 GHz as currently specified. We also recommend that a peak power output of 1W be allocated for UWB emissions in this 200 MHz segment, with directional antenna gains of up to +6 dBi. As in the current allocation, peak output power will be reduced on a dB for dB basis for any antenna gain exceeding +6 dBi. In addition, we recommend that any decrease in instantaneous bandwidth below 200 MHz result in a dB for dB reduction in peak output power. (Thus, for example, a 100 MHz UWB emission would only be permitted a peak power output of 0.5 W, etc.)

The reason for recommending the above rule change for the 5.15 to 5.35 GHz portion of the U-NII band is to permit high data rate (20 Mb/s), digital communications for short range, in-building applications in which multipath cancellation can be severe (cf. Section 2.4.3 above). The wider bandwidth allocation would permit the use of recent techniques for leading edge detection of UWB pulses which has been demonstrated to perform extremely well in high multipath environments.

Appendix A
Multispectral Solutions, Inc.
Military and Government Ultra Wideband Systems

1. **Title:** ***Short Pulse Communications System (SPCS)***



Device Type: **Handheld LPI/D Communications**

Brief Description:

High data rate, UWB handheld transceiver for low probability of intercept and detection (LPI/D), full duplex voice and data communications. Radios have been extensively tested and evaluated by numerous Government agencies and commercial organizations. (Note: The frequency coverage for these radios overlaps the GPS frequency assignment at 1.575 GHz; however, they have been operated in close proximity (inches) to GPS receivers without any noticeable degradation.)

Frequency Ranges: L-band

Bandwidths: 27% fractional

Data Rate: 9.6 kb/s to 128 kb/s digital voice and data

Peak Power: 2 W

Average Power: 640 μW (worst case at highest data rate)

Average Power Density: 1.6 pW/Hz (worst case at highest data rate)

Range: 1 to 2 kilometers (handheld line-of-sight); 10 to 20 miles with small gain antennas.

2. **Title:** ***LPI/D Groundwave Communications System (LGCS)***

Device Type: **Non Line Of Sight LPI/D Communications**

Brief Description:

Development of prototype UWB voice/data radios for non line-of-sight communications in high interference environments. Demonstrated UWB capability for foliage and obstacle penetration and techniques for interference suppression in highly dense electromagnetic environments.

Frequency Ranges: 30 to 50 MHz

Bandwidths: 20 MHz (50% fractional)

Data Rate: 9.6 kb/s to 128 kb/s digital voice and data

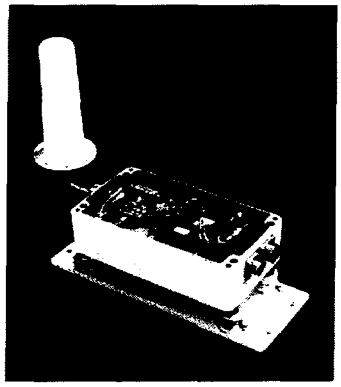
Peak Power: 16 W

Average Power: 102 mW (worst case at highest data rate)

Average Power Density: 5.1 nW/Hz (worst case at highest data rate)

Range: 1 to 5 miles over land, 10+ miles over water.

3. **Title:** ***Low Probability of Intercept Packet System (LIPS)***



Device Type: **LPI/D Communications**

Brief Description:

Prototype UWB packet radios for LPI/D covert communications of GPS coordinate information. Developed high anti-jam capability for UWB systems. Units designed to operate with on-board GPS receivers (in-band) without affecting GPS performance. GPS antenna was less than one foot from UWB antenna.

Frequency Ranges: L-band

Bandwidths: 400 MHz (27% fractional)

Data Rate: 9.6 kb/s to 128 kb/s digital voice and data

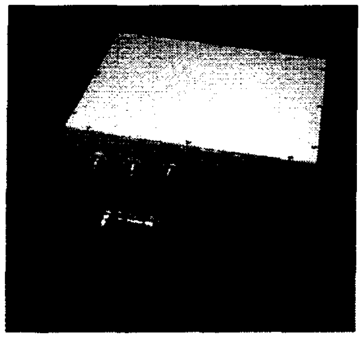
Peak Power: 10 W

Average Power: 3.2 mW (worst case at highest data rate)

Average Power Density: 8.0 pW/Hz (worst case at highest data rate)

Range: 3 to 4 miles with small, omnidirectional antennas.

4. Title: ***Hummingbird UAV UWB Collision Avoidance Sensor***



Device Type: **UWB Collision Avoidance Sensor**

Brief Description:

Ultra wideband obstacle/collision avoidance sensor for Marine Corps *Hummingbird* unmanned air vehicle (UAV). System proved capable of detecting small diameter (0.25") suspended wires. C-band UWB radar has peak output power of 0.2W and average output power of less than 4 μW. System incorporates linear forward-looking phased array, and broad beamwidth side-looking antennas, for use in autonomous control.

Predecessor of *Hummingbird* system was developed for the Naval Air Systems Command as a multifunction precision altimeter, collision avoidance sensor and low data rate communications system.

Frequency Ranges: 5.4 to 5.9 GHz

Bandwidths: 500 MHz (8.9% fractional)

Pulse Repetition Frequency: 10 kHz

Peak Power: 0.2 W

Average Power: 4.0 μW

Average Power Density: 0.008 pW/Hz

Range: Collision avoidance 10 feet to 5000 feet (depending upon radar cross section); Altimeter 10 feet to 15,000 feet.

5. **Title:** ***Multifunction UWB Communications and Radar System***

Device Type: **Multifunction UWB Communications and Radar System**

Brief Description:

Development of LPI/D UWB command and control uplink (100 kb/s), UWB high speed (6 Mb/s) video downlink and UWB precision radar for UAV and missile applications.

Frequency Ranges: 5.4 to 5.9 GHz

Bandwidths: 500 MHz (8.9% fractional)

Data Rate: 6.0 Mb/s video and command & control; 100 kpps radar mode

Peak Power: 0.25 W

Average Power: 3 mW (high-speed video mode), 50 μW (radar mode)

Average Power Density: 6 pW/Hz (high-speed video mode), 0.1 pW/Hz (radar mode)

Range: 3 to 5 miles LOS with omnidirectional antenna on platform, 2 foot parabolic dish on ground station

6. Title: ***Navy Expendable Wideband Data Link (NEWDL) – In development***

NO PICTURE AVAILABLE

Device Type: **High-speed UWB Video Communications System**

Brief Description:

Development of miniaturized, high-speed (25 Mb/s) UWB video data link. UWB system to fit inside 5" Extended Range Guided Munition (ERGM) modified for gun-launched UAV.

Frequency Ranges: 1.3 to 1.7 GHz

Bandwidths: 400 MHz (27% fractional)

Data Rate: 25 Mb/s video and command & control

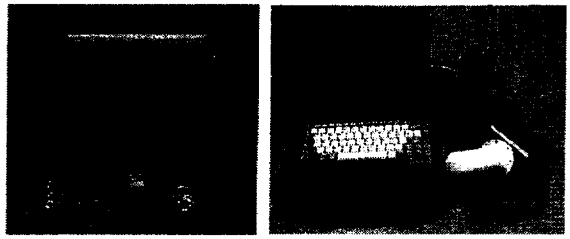
Peak Power: 10 W (estimated)

Average Power: 625 mW

Average Power Density: 1.6 nW/Hz

Range: 60 nautical miles LOS with omnidirectional antenna on UAV platform, parabolic dish on ground station

7. Title: ***UWB Vehicular Electronic Tagging and Alert System (VETAS)***



Device Type: **Short Range UWB Tagging System**

Brief Description:

Development of micropower, miniature, automobile-mounted UWB tag for the identification of suspended drivers. Micropower UWB transmitter for short range (vehicle-to-vehicle and vehicle-to-roadside) communications applications in severe multipath.

Frequency Ranges: 1.3 to 1.7 GHz

Bandwidths: 400 MHz (27% fractional)

Data Rate: 115.2 kb/s

Peak Power: 0.25 W

Average Power: 72 μW

Average Power Density: 0.18 pW/Hz

Range: 2000 feet from moving vehicle to stationary roadside reader.

8. Title: *DARPA SUO SAS* (Small Unit Operations, Situational Awareness System) – In development

Device Type: **UWB Precision Geolocation System**

Brief Description:

Development of UWB precision geolocation system for urban warfighter applications. MSSI UWB approach selected for LPI/D and multipath performance. Development of UWB beacon transmitters and roving UWB receiver.

Frequency Ranges: 1.3 to 1.7 GHz

Bandwidths: 400 MHz (27% fractional)

Data Rate: 500 kb/s

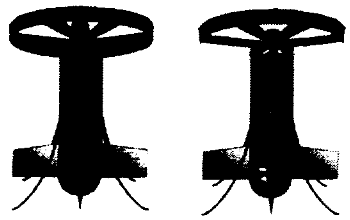
Peak Power: 2 W

Average Power: 2.5 mW

Average Power Density: 6.25 pW/Hz

Range: 0.25 to 1 kilometer in obstructed, multipath environment

9. Title: ***DARPA MAV (Micro Air Vehicle) – In development***



MSSI UWB Video Downlink for
DARPA Micro Air Vehicle

Device Type: **UWB Video and Command & Control Communications System**

Brief Description:

Development of microminiature, UWB telemetry and video downlink for Micro Air Vehicle (4" diameter blade span helicopter).

Frequency Ranges: 1.3 to 1.7 GHz

Bandwidths: 400 MHz (27% fractional)

Data Rate: 128 kb/s (compressed video)

Peak Power: 0.5 W (estimated)

Average Power: 160 μW

Average Power Density: 0.4 pW/Hz

Range: 4 kilometers unobstructed LOS, 0.25 to 1 kilometer in obstructed, multipath environment

10. Title: ***UWB Intrusion Detection System – In development***

Device Type: **Intrusion Sensor Radar**

Brief Description:

Development of high sensitivity, micropower handheld UWB intrusion detection system for through-wall penetration.

Frequency Ranges: L-band

Bandwidths: 400 MHz (27% fractional)

Data Rate: 100 kpps pulse repetition frequency

Peak Power: 1 W

Average Power: 250 μW

Average Power Density: 0.625 pW/Hz

Range: 10 feet to 2000 feet (depending upon mode of operation)

11. Title: ***DARPA Exdrone Video Link – In development***

Device Type: **LPI/D Video and Command & Control Communications**

Brief Description:

Development of LPI/D UWB command and control uplink (100 Kb/s) and UWB MPEG-compressed video downlink (up to 6 Mb/s) for fixed-wing unmanned air vehicle. System includes airborne, ground station and soldier vest-mounted units.

Frequency Ranges: C-band

Bandwidths: 400 MHz (27% fractional)

Data Rate: 9.6 kb/s to 128 kb/s digital voice and data

Peak Power: 10 W

Average Power: 3.2 mW (worst case at highest data rate)

Average Power Density: 8.0 pW/Hz (worst case at highest data rate)

Range: 3 to 4 miles with small, omnidirectional antennas.

12. Title: ***UWB Backup Sensor***

Device Type: **UWB Radar System**

Brief Description:

Short range UWB radar for detection of personnel, vehicles and other objects behind large construction and mining vehicles.

Frequency Ranges: 5.4 to 5.9 GHz

Bandwidths: 500 MHz (8.9% fractional)

Data Rate: 100 kpps

Peak Power: 0.25 W

Average Power: 50 μW

Average Power Density: 0.1 pW/Hz

Range: 10 to 350 feet behind vehicle.